R&D FACILITY

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DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
FEDERAL ENERGY TECHNOLOGY CENTER

FILTRATION
PROJECT

A NEW HOT GAS CLEANUP FILTER DESIGN METHODOLOGY

Capabilities

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The fluid dynamics of Hot Gas Cleanup (HGCU) systems having complex geometrical configurations are typically analyzed using computational fluid dynamics codes (CFD) or bench-scale laboratory test facilities called cold-flow models (CFM). At the present time, both CFD and CFM can be effectively used for simple flows limited to one or two characteristic length scales with well-defined boundary conditions. This is not the situation with HGCU devices. These devices have very complex geometries, low Reynolds number, multi-phase flows that operate on multiple-length scales. For this reason, both CFD and CFM analysis cannot yet be considered as a practical engineering analysis tool for modeling the entire flow field inside HGCU systems.

The thrust of this work is to provide an aerodynamic analysis methodology that can be easily applied to the complex geometries characteristic of HGCU filter vessels, but would not require the tedious numerical solution to the entire set of transport equations. The analysis methodology performs the following tasks:

- Predicts problem areas where ash deposition will most likely occur;

- Predicts residence times for particles at various locations inside the filter vessel;

- Lends itself quickly to major design changes;

- Provides a sound technical basis for more appropriate use of CFD and CFM analysis; and

- Provides CFD and CFM analysis in a more focused way where it is needed.

The technical approach taken here is to first solve for the general flow field using panel techniques. These techniques provide the exact solution to the flow field using a greatly reduced form of the transport equations and is applied only at panels that define the geometry. Thus the flow field is solved for without the need of a finite difference or finite element grids. Since the solution is exact, there are no stability or convergence problems that are typically found in other CFD solvers. This method is particularly suited for problems having complex geometries. Thus, the effect of major geometric design changes on the global flow field can be quickly assessed without major efforts in CFD or CFM analysis so that design optimization may be performed.

After a simple global solution is obtained for any particular geometry using panel methods, regions in the flow field where secondary flows develop would be revealed. These secondary flows are then analyzed in greater detail using the conventional methods of CFD and CFM analysis.

FETC

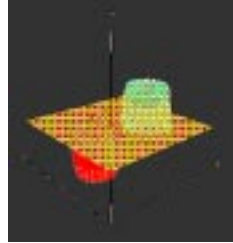# A New Hot Gas Cleanup Filter Design Methodology

Opportunities

- **General Fluid Dynamic Analysis Using Panel Methods and Other Global Techniques**
  - General properties of complex flow fields identified.
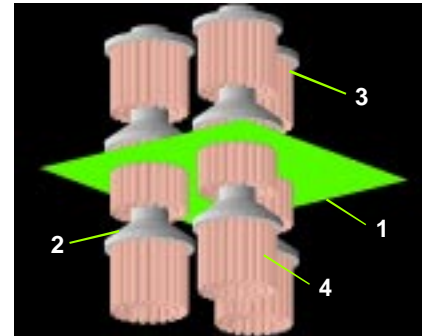 - Special points of interest in the flow field identified.
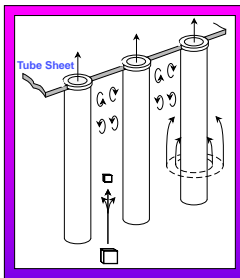
Time Sequence of Back Flush

Engineering Model

1. Solution Plane
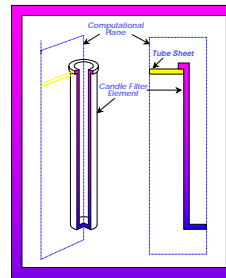2. Shed Roof
3. Tube Sheet
4. Candle Filter Bunch

- **Computational Fluid Dynamic Analysis (CFD)**
  - Analysis performed on limited scale using the right model at the right place.
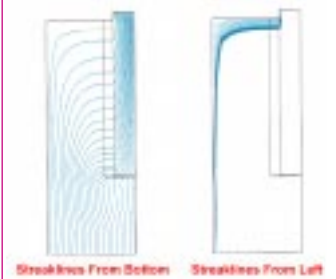 - Different models for different situations.

Candle Filters
(Axial Flow)

Tube Sheet Deposition:
Analysis of Small Scale Flow

Streaklines

- **Bench Scale Analysis or Cold-Flow Modeling (CFM)**
  - Each analysis is set up using the laws of dynamic similarity as a basis for scaling.
  - This ensures that the results obtained in the laboratory are extendable to the prototype and can be used for engineering design calculations.
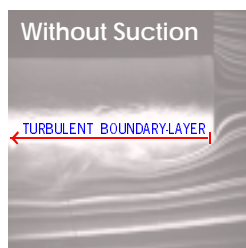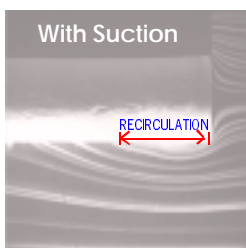
  - *Geometrical Similarity* (length scale matching)

  - *Kinematic Similarity* (flow visualization)
    - Smoke Wire Stream Line Tracing
    - Hot Wire Anemometry
    - Hot Film Anemometry
    - Schlieren
    - Focused Schlieren
    - Laser Doppler Anemometry (LDA)
    - Particle Image Velocimetry (PIV)

  - *Dynamic Similarity* (Newton's Laws - dimensionless group matching)

- Reynolds Number	- Eckert Number	- Euler Number
- Stanton Number	- Mach Number	- Coefficient of Lift
- Froude Number	- Coefficient of Drag	- Rossby Number
- Coefficient of Pressure	- Strouhal Number	- Skin Coefficients
- Pressure Gradient Matching	- Heat Transfer Coefficients	- Prandtl Number

With Suction

RECIRCULATION

Without Suction

TURBULENT BOUNDARY-LAYER

Axial Tip Flows in Water Tunnel